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BRE Trust Quarterly Review April - June 2019

Prepared by the BRE Trust Secretariat

Summary of this report

This report presents highlights from the research, education and dissemination activities supported by the BRE Trust during April to June 2019. It also includes the second in a series of reviews of key work areas, this time covering the topic of fire safety research.

Fire safety research – The investigations of BRE's Fire Safety Research team receive significant BRE Trust support, and deliver fundamental knowledge that has practical impacts on everyday life.

Research project reports

Circadian rhythms. A study of 23 people working in an open-plan office has been carried out to translate experimental knowledge on the effects of workplace lighting into real-world good practice.

Indoor air quality sensors and monitors. An investigation of the performance of various commercially available VOC and CO₂ sensors/monitors, when challenged by realistic levels of these pollutants.

Key Performance Indicators. There is a well recognised need for a definitive list of built environment Key performance Indicators (KPIs).

New projects

100 years of council housing

In the 100th anniversary year of the 1919 Housing Act, this project will produce a BRE Trust report on '100 Years of Council Housing'.

Housing in the UK 2017

The data in the four separate housing surveys for England, Scotland, Wales and Northern Ireland, are being combined into one UK-wide report on UK Housing.

Adapting with age

National housing survey data has been used to provide Adapting with Age with information on the presence of adaptations in UK homes.

University Partnerships

Quarterly reports from the University of Edinburgh Centre for Fire Safety Engineering and the University of Bath Centre for Innovative Construction Materials.

University of Hertfordshire – note on the delivery of BEng and Meng Civil Engineering courses.

PhD studentships

New – applications are being invited for a PhD studentship on using clay in low-carbon cements, being offered by the Trust in partnership with Coventry University.

Completed – two studentships have been completed, one on flood resilience at Bath University and one on coupled hybrid modelling for fire engineering at Edinburgh University.

Ongoing – brief updates are given on seven of the current Trust supported PhD studentships.

Regular reports

Sales and downloads – updates from the BRE Bookshop and Construction Information Service (CIS). Retail sales totalled 778 units including 326 through IHS retail. CIS downloads totalled 27,637.

Designing Building Wiki – updates on general performance, BRE articles and BREEAM Wiki. There were 398 BRE articles on Designing Buildings Wiki, the contents of which have been viewed 37,037 times.

Event and publications:

- Wellness and Biophilia Symposium, 6-7 June.
- BRE Trust Annual Review 2018-19.

Appendices

Lists of current projects and studentships.

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Fire safety research review

A review of completed and ongoing fire safety research projects, their impacts and dissemination, plus notes on possible future research topics.

Investigations by BRE's Fire Safety Research team deliver fundamental knowledge that has practical impacts on everyday life. The BRE Trust has provided – and continues to provide – significant funding support to the team's studies, which have so far addressed questions including:

- Why do people die in fires and what can be done to save lives?
- Why do false alarms occur and how can they be reduced?
- How can new fire detection technologies be robustly tested so that they are fit for purpose?
- How can visual warnings be given to warn the deaf and hard of hearing in the event of a fire?
- Are tests for assessing smoke alarms and smoke detectors, developed decades ago, still valid although materials used in buildings have changed significantly?
- How can large refuse fires (which often last for weeks) be put out effectively?

These investigations are characterised by:

Industry collaboration – working with industry partners throughout the process provides the vital industry commitment and engagement – in the form of cash, equipment or data – from the outset of each research project to the implementation of its findings.

Wide ranging dissemination – led by Raman Chagger, the Fire Safety Research team puts a strong emphasis on making its research findings widely available to those who will most benefit from putting them into practice. This includes presenting at events and producing detailed reports for experts in this field, video summaries for the wider market, and articles for journals and trade press.

Completed research projects

Causes of false fire alarms in buildings BRE Trust: £10k, Partners: £20k in kind Characterising the smoke from modern materials and evaluating smoke detectors BRE Trust: £10k, Partners: £13k, £15k in kind Effectiveness of visual alarm devices BRE Trust: £5k for project report production. Live investigations of false fire alarms BRE Trust: £19.25k, Partners: £22.5k, £50k in kind Testing the performance of multi-sensors

BRE Trust funding: £20k, Partner support: £63.5k in cash, £50k in kind.

Developing test methods to assess video flame and video smoke detectors

BRE Trust: £30k, Partners: £22k, £55k in kind. Suppression of biomass fires BRE Trust: £12.4k, Partners: £20k, £15k in kind.

Current projects

Fire protection: digital technologies and personal wellbeing

BRE Trust: £28.5k, Partners: £37.5k, £55k in-kind **Determining the optimum replacement period for smoke detectors**

BRE Trust: £26.3k, Partners: £40k, £60k in kind.

Potential future research topics

- Performance of complex multi-sensor detectors to fire and false alarm tests.
- Contaminated heat detector performance.
- Detector positioning and response times.
- Carbon monoxide.

A new website dedicated to both presenting the research findings and engaging with the industry, is at

www.bregroup.com/firesafetyresearch

Completed Projects

This project investigated why false alarms occur in buildings and identified approaches that could reduce their occurrence. Kings College London (KCL) and Buckinghamshire & Milton Keynes Fire Authority (BMKFA) contributed basic data for analysis by BRE.

Findings

A review of data from false alarm incidents provided by KCL, revealed that replacing existing detectors with intelligent multi-sensor detectors (that detect more than one fire phenomena) was the action that could potentially reduce false alarms by the greatest amount (69%).

Discussions with BMKFA and analysis of its false alarm trends showed that educating building owners, responsible persons and the public can significantly reduce false alarms – as simple measures can cause notable reductions – and also confirmed that increased multi-sensor detector use can avert false alarms from common causes such as cooking fumes and steam.

Further investigations

To further understand the causes of false alarms, it was proposed that an investigator attend premises with fire and rescue services whilst false alarms were in progress. This led to follow-on research on *Live investigations of false alarms*, summarised on page 7. The findings on multi-sensors detectors have been further investigated in the project, *The performance of multi-sensors in fire and false alarm tests*, summarised on page 7.

Impact

The knowledge gained from this and the follow-up false alarms study has enabled BRE to offer a consultancy service to help organisations reduce false alarms.



Characterising smoke from modern materials and evaluating smoke detectors

The materials used in modern homes have changed significantly in recent decades. This research investigated whether smoke detectors could respond to the smoke produced from new materials during a fire.

The four test fires used in standards to assess smoke detectors were developed in the 1980s and represent a broad range of smoke types expected in commercial and domestic environments at the time.

The smoke characteristics for a range of new materials in smouldering and flaming modes that were measured and compared with the existing four test fires. The performance of twelve approved ionisation and optical smoke detectors to the smoke produced from these alternative materials was also assessed.

Findings

Twenty-nine test fires were conducted and sixteen were found to be within the range bounded by the existing smouldering wood fire (TF2) and flaming liquid fire (TF5) test fires from smoke detector standards. The smoke alarms and detectors were installed on the ceiling and the wall and then exposed to the smoke from the test fires. For all the complete fires there were six no responses and 270 responses which represents a 97.8% pass rate.

It is evident that ionisation or optical detectors used in commercial and domestic environments are capable of responding to a broad range of fires inside and outside the limits from existing standards. It was confirmed that both ionisation and optical smoke detectors are attuned to detecting certain types of fires and that existing standards remain suitable for assessing these technologies.

Impact

The knowledge gained from this study enabled more challenging test fires to be developed that were used during the multi-sensor research (page 7) work. These are expected to contribute towards the Loss Prevention Standard (LPS) for false alarm resistance and will demonstrate the ability of more advanced detectors to respond to more challenging fires.

Visual alarm devices – their effectiveness in warning of fire

Visual alarm devices (VADs) provide visual warning of fire for deaf and hard of hearing people, as well as in areas of high ambient noise (e.g. factories) or where a silent alarm is preferred (e.g. operating theatres). There is much to be learnt about what type of visual signal provides the most effective warning for people.

This project investigated the pulse duration of VADs by comparing the responses of a group of participants to flashing Xenon and LED devices of varying pulse durations. One Xenon device, three cool white LED devices (of 40, 20 and 10 millisecond (ms) pulse durations) and two warm white LED devices (of 40 and 20ms pulse durations) were used. The flashing signals were presented individually to 96 participants who were seated in front of a screen and occupied in a written task. The tests were performed in high and low ambient light level conditions. The devices were flashed one at a time starting at a distance of 19m and were gradually brought closer to the screen until the subjects responded.

Findings

Analysis of this data revealed that as the pulse durations of LED devices shorten the attentiondrawing effectiveness increases. It also demonstrated no significant difference in responses between warm white LED devices and cool white LED devices. The Xenon and 10ms cool white LED device had similar responses.

Impact

This work has led to changes in US and British codes of practice and has influenced manufacturers of VADs to produce devices with shorter pulse durations. Further research work, funded by 13 VAD manufactures, is currently in progress to identity other factors that influence the effectiveness of visual fire warning for people.



Live investigations of false fire alarms

Conceived as a result of the work reported on page 5, this project aimed to identify the fundamental causes of false fire alarms, using a fire alarm industry expert to investigate false alarms as they occurred in the field in the greater Glasgow area.

The investigator joined Scottish Fire and Rescue Service crews on live callouts and, following a comprehensive investigation, completed online reports for each false alarm – this form of 'live' false alarm investigation had not previously been conducted.

Recommendations

Following analysis of the data gathered, recommendations were made across nine different stakeholder groups ensuring that fire and rescue services, fire risk assessors, business owners, fire alarm contractors as well as trade associations and others all play their part in collectively reducing false alarms in the UK.

One of the recommendations was that, "Manual Call Points (MCPs) at risk of being triggered should be fitted with protective covers". This has been adopted and implemented in the code of practice BS 5839-1 for commercial fire detection systems. It is anticipated that the resulting installation – and upgrading in the field – of cover protected MCPs will reduce false alarms due to MCP misuse.





The project report and a video summary is available at: www.bregroup.com/ firesafetyresearch

The performance of multi-sensors in fire and false alarm tests

The reliable early detection of fire with minimal false alarms over a broad range of applications is a challenge. The detection of smoke-like phenomena commonly found in the service environment, such as cooking fumes, steam, aerosols and airborne dust, contribute to false alarms.

Previous research (page 5) has shown that the greater use of multi-sensor detectors could help to reduce false alarms from such common causes.

Multi-sensor detectors use a combination of more than one type of sensor – smoke, heat or carbon monoxide – to detect the presence of a fire. A research group, comprising the Fire Industry Association, BRE and fire detector manufacturers, investigated the immunity of multi-sensor detectors containing smoke and heat sensors to common causes of false alarms, as well as to real fires.

Five tests were developed and used during this research – water mist, dust and aerosol tests were performed at the University of Duisburg-Essen, and toast and cooking tests in the BRE Fire Test room.

Findings

In all of the false alarm tests the multi-sensors, on average, operated after the smoke detectors. It was generally found that the more sophisticated the multi-sensors were, the less prone they were to common causes of false alarms, whilst their ability to detect fires was not compromised.

Impact

This research has led to further work with multisensor detectors manufacturers to perfect the false alarm tests. Once completed, these will support the development of a Loss Prevention Standard (LPS) and codes of practice for smoke and multi-sensor detectors.

Developing test methods to assess video flame and video smoke detectors

Video fire detectors emerged as a new means of fire detection around 15 years ago, particularly in large indoor spaces such as in atria, warehouses and industrial complexes.

A video detector is alerted to fire by identifying – though analysis by complex algorithms – the characteristic signatures of smoke or flame within its camera's field of view. There are two detector types, video flame detectors (VFDs) that recognise flaming fires, and video smoke detectors (VSDs) that are alerted by moving smoke. Their ability to 'see' flames or smoke (provided there is direct line of sight) enables a quicker response than generally achievable by traditional detectors, and can also provide a visual verification of fire.

Due to the complexity of video fire detectors, there are no defined and robust methods of assessing their capabilities for testing and certification purposes. The greatest obstacle has been a lack of benchmark tests to perform the fundamental tests of repeatability, reproducibility and environmental testing defined in the EN 54 Fire detection and fire alarm systems standard. Operational performance tests are also needed to verify the absolute capabilities of video detectors in detecting the fires anticipated in service environments.

Collaborative research programme

A BRE Trust supported research programme was established by BRE, in collaboration with the FIA and video fire detector manufacturers, to develop these tests. The group has developed methods for bench testing and full-scale fire testing of these systems, to gain the necessary underpinning knowledge on performance capabilities. It is now expected that these methodologies will support the development of a test standard and associated code of practice.

Project completed this quarter

Suppressing biomass fires using wetting agents

Biomass fuels derived from organic matter, used to generate heat and/or electricity, are typically stored in large outdoor piles or waste processing plants. In some circumstances they can ignite and may take a long time to control, causing severe environmental damage. The Fire Industry Association had identified wetting agents (added to water) that increase the spreading and absorption of water on solid substrates, potentially increasing its effectiveness in extinguishing biomass fires. This research extended that work by performing tests on a larger scale.

Experimental tests were performed in which a steel drum was filled with 37.5 kg of biomass fuel, which comprised of commercial waste including paper, card, wood, textiles and plastic. The fuel was then ignited using a propane burner that was applied for five minutes. Using this standard methodology, multiple experiments were conducted with a range of suppression methods, and temperature profiles and quantity of run-off compared. The methods of suppression had a range of application rates and durations, comparing water only or water plus additive, and the results were shared with the FIA steering group. The variability of the fuel type resulted in issues with developing a consistent repeatable test fire, and therefore further work is required.

Further work

There is interest in repeating this work using coal as a fuel that, while not exactly replicating biomass fuel, is expected to give a more consistent fire. It is anticipated that this methodology will then be developed, leading to a Loss Prevention Standard (LPS) for assessing the effectiveness of wetting agents.



Current Projects

Fire death and serious injury investigation

UK domestic fire death numbers appear to have plateaued in recent years after more than three decades of decreasing fatalities. In this project a group of fire experts is analysing data gathered by Fire and Rescue Services and reviewing the causes of fire deaths and the circumstances of serious fire related injuries. The outputs will be used to produce guidance on the effect that using new technologies or services can have on reducing deaths and injury from fire in homes.

Project update

Factors influencing a typical fire fatality and serious injury are emerging from the first phase of this review. So far 14 recommendations have been proposed to potentially reduce fatalities and injuries, including the more effective use of existing technology, greater use of combined detection/suppression systems and identifying further areas to research such as fires from electrical appliances.



As older and vulnerable people populations increase, interventions need to be in place to ensure that fire deaths and serious injuries do not follow this trend.



The Trutest detector sensitivity tester being used onsite to get an alarm response from a commercial smoke detector.

How long before replacing smoke detectors?

UK codes and regulations have no recommendations for when smoke detectors should be replaced. Detector performance and sensitivity changes with time and as components become dusty and electrical components degrade. This project is testing smoke detectors in domestic and commercial environments to identify the mean and spread of their sensitivities with age and analysing this data to propose replacement periods. This will enable UK codes and guidance to be updated and will influence other countries to adopt more appropriate replacement periods based on research.

Project update

Following testing at Loughborough University, the University's Fire Safety Officer has asked BRE to perform additional tests at some Loughborough premises to establish whether the older detectors need replacing. If there were similar requests from other organisations, this could lead to a new BRE service that assesses old smoke detectors in commercial premises and provides guidance.

Proposed future studies

Performance of complex multi-sensor detectors to fire and false alarm tests

It is reported by manufacturers that multi-sensors incorporating a combination of other sensors have greater resistance to false alarms and can be more sensitive to fires than optical heat multi-sensors. Previous BRE Trust supported research (see page 7) has also found that optical heat multi-sensors have greater resistance to false alarms than standard optical detectors.

Building on the previous study, research is proposed to validate the manufacturers' claims. It will generate independent evidence on the performance capabilities of more complex multi-sensors to a series of four, more challenging test fires and at least five different false alarm tests.

The performance of contaminated heat detectors

Heat alarms in kitchens, where the majority of fires in the UK occur, are subjected to environmental factors that may delay an alarm response. When attending fires in homes, fire and rescue services report *whether* a detector operated, but not *when* it operated as they have no way of knowing. A delayed response could delay detection, giving less time for occupants to intervene or escape.

Current standards do not test whether the build-up of deposits on sensors are sufficient to affect performance. The proposed research will measure a number of domestic heat alarms of different ages, types and levels of contamination.

Detector positioning and associated response times

Many historic buildings have fire detectors that are positioned to minimise their visual impact, rather than maximise their ability to detect fire. While BS 5839-1, the code for commercial fire detection systems, includes recommendations that produce effective fire alarm systems, not all of these are based on research results. The recommendations for spacing smoke detectors (which are used in the majority of commercial premises), for example, were based on experience rather than research. Also, the optimum carbon monoxide (CO) and smoke detector spacing with increasing height are not known.

The recommendations in BS 5839-1 are based on anecdotal evidence from the industry, which suggests that CO detectors in commercial premises may require spacings that differ from those of smoke detectors – but there is neither research to confirm this nor evidence to guide what it should be. The objective of this proposed research project is to identify optimum spacing for CO and smoke detectors located on ceilings and walls.

Carbon monoxide research

Accidental acute carbon monoxide (CO) poisoning results in around 30 recorded deaths and 200 hospitalisations each year in England and Wales. Recent Department of Health figures indicate that there are 4,000 CO poisoning attendances at A&E departments in England each year. Much can be done to reduce these numbers, particularly with increased use of CO alarms in domestic dwellings (current UK CO detector ownership is ~30%).

The aim of this proposed project is to unlock the key areas that require research, and support the changes that will bring about a step change in both CO ownership and awareness of the dangers of CO poisoning. It is anticipated that a combination of research into how CO levels become toxic, the use of video simulation techniques to highlight the dangers of CO in the built environment, and a high-profile awareness raising campaign (e.g. through the press), will help to achieve these objectives.

Outputs and Impacts

Outputs

The technical reports that are generated at the end of a project are used as the basis for writing briefing papers and trade press articles that are summarised in the flow chart below.



Impacts

To date six briefing papers and three summary videos have been produced, all available free of charge from the Fire Safety Research website. The projects are followed up to ensure that not only are they promoted, but also that the findings are implemented and, where possible, BRE services are developed.

Some of the impacts of this work have included:

- being used to revise existing codes of practice, e.g. BS 5839-1 for commercial fire detection systems, or develop new ones, e.g. LPCB CoP 0001 for visual alarm devices,
- supporting the development of product test standards, e.g. BS EN 54-23 for fire detection and alarm systems,
- being adopted and integrated into processes used by fire and rescue services,
- leading to more research that has generated further knowledge,
- supporting the development of new product testing and certification services at BRE,
- leading to a new false alarm investigation service at BRE,
- FIA-produced guidance documents on specific products for industry,
- supporting the FIA to produce qualifications for fire detection and alarm engineers,
- providing guidance for building owners, managers and responsible persons,
- informing product manufacturers on how to improve their products.

Fire Safety Research website

The BRE Fire Safety Research website has recently been updated to more effectively promote this work and the impacts that have resulted.

The new site's introductory page links to individual project pages with clear information on the research projects, the partners involved and the outcomes and impacts of the work. Each project page also provides opportunities for users to subscribe to enewsletters to be kept informed of future research work, link to free briefing papers and (where available) video summaries and leave feedback about these publications.

Visit the Fire Safety research website at: www.bregroup.com/firesafetyresearch

New projects

100 Years of Council Housing – \pounds 9k Trust, \pounds 8.25k cash contribution UK Housing in 2017 – \pounds 8k Trust, \pounds 11k cash and in-kind contribution Adapting with Age – \pounds 2.5K Trust

100 Years of Council Housing

This year marks the 100th anniversary of the 1919 Housing Act which introduced the concept of 'council housing' to the UK. It also led to the creation of the Building Research Station – now BRE – to ensure that new housebuilding was undertaken in the most effective and efficient way, using modern building materials and techniques.

This project, in partnership with the Ministry of Housing, Communities and Local Government (MHCLG), will produce a BRE Trust report on '100 Years of Council Housing'. The report will discuss the changing face of social housing and the people who live in there, and will ask the question: *Who is our future council housing for and what should it look like*?

The BRE project team will compile and analyse statistics from the latest and earlier English Housing Surveys (and other data sources), on council housing stock and the people who live there, to see how this sector and its occupants have changed over time.

It will provide robust evidence on the current state of council housing in England, and show the type of council housing that has been most successful and has survived over the last 100 years.

The report will be launched at a forthcoming BRE Housing Conference early next year. The event will follow the format of the successful BRE conference on 50 Years of UK National Housing Surveys in 2017, which was also accompanied by a BRE Trust funded publication that has been widely read and reported. BRE leads the world in measuring the condition and performance of housing stock and how it changes over time. The BRE Trust funding in this area of work has been used to promote housing interventions that promote health and wellbeing and to make the case for building better quality housing.

This research will support a fundamental principle of the BRE Trust, which is that better housing equals better health and wellbeing and a better built environment. It will be of value to anyone making a case for investment in the existing housing stock, or promoting better quality new housing, particularly social housing.



1950s Council Houses

UK housing in 2017

This project is taking advantage of an opportunity to combine the data in the four separate housing surveys for England, Scotland, Wales and Northern Ireland, into one UK-wide report on *Housing in the UK 2017*. The report will provide national comparisons of housing typology, condition and the costs of poor housing.

This follows a similar opportunity in 2013, when all four UK national housing surveys had recently been completed, and BRE had the data and the capability to compile the information into one report for the first time.

The 2013 report was sponsored by the BRE Trust and was very well received, particularly by BRE's four national housing survey clients. It also proved of value to international organisations such as the United Nations, European Union and World Health Organisation, who are interested in UK-wide housing statistics rather than those of the four separate UK nations. The report has become the recognised source for UK housing statistics but is now getting out of date.

The four UK surveys are held at varying intervals of 1-8 years, but were once again aligned in 2017, enabling the production of updated UK national housing statistics from the:

2016/17 English Housing Survey,

2016/17 Scottish House Condition Survey,

2016/17 Northern Ireland House Condition Survey, 2017/18 Welsh Housing Conditions Survey.

With encouragement and support from the Ministry of Housing, Communities and Local Government, the Scottish Government, the Welsh Government and the Northern Ireland Housing Executive, a BRE team is compiling a report providing information on:

- The history of UK housing surveys,
- dwelling age and type, size, construction, materials,
- tenure,
- indicators of housing quality and condition,
- Heating, fuel type, insulation and energy efficiency,
- the cost of poor housing,
- comparisons between the UK and other countries.

The document will be made freely available and widely promoted on the BRE website.

Adapting with Age

The Adapting with Age team at the National Housing Federation's Creating Our Future programme, works to tackle the issues faced by an ageing population with a focus on helping people to live well and longer in their own homes.

To support this work, the BRE Trust has funded the BRE Housing Centre to access national housing survey data to provide Adapting with Age with information on the presence of home adaptations. This has included:

- the number of properties that have grab rails installed,
- The number of properties without level access,
- the number of properties with a bathroom adapted for disabled people,
- the number of older people and those with a long-term limiting illness that had grab rails, level access or a bathroom adapted for disabled people.



An example of an adapted bathroom.

Completed project

Circadian Lighting - £35k Trust, £45k cash and in-kind contribution Indoor air quality sensors and monitors - £50k Trust, £25 in-kind contribution KPI Feasibility Study - £15k Trust, £2.5k in-kind contribution

Circadian Lighting

A study of 23 people working in an open-plan office has been carried out by research scientists at BRE – with BRE Trust funding support – to translate experimental knowledge about the effects of lighting in the workplace into real-world good practice.

Circadian rhythms

Circadian rhythms control human alertness and sleep, and the release of hormones. Daytime exposure to light, especially blue light, helps synchronise the circadian clock, enabling us to feel alert during the day and sleepy at night. But many people work in poorly daylit spaces with relatively low levels of electric light, where it may be hard for their bodies to maintain their circadian rhythms.

Dynamic 'circadian' lighting is being marketed using dimmable, colour-tuning LEDs to give brighter, bluer light in the middle of the day, and dimmer light – with less blue – later in the day when it is time to relax. However, little or no research has been done on the best way to control this tuneable lighting under real-world conditions. Research was needed to help translate experimental knowledge into practice and investigate the effects of dynamic lighting and its timing on how people feel (i.e. their subjective assessments), and their activities and reported sleep.

Lighting conditions investigated

This research took the form of a BRE field study, with 23 participants working in an open plan office at the University of East Anglia. Four conditions were administered over several weeks during winter months:

Condition 1 – Old constant fluorescent lighting – i.e., the office's existing lighting – from 19 February to 2 March 2018.

Condition 2 – **New dynamic LED system** – with *variable* LED lighting at a *lower* level – from 12-23 March 2018.

Condition 3 – **New dynamic LED system** – with *variable* LED lighting at a *higher* level – 12-23 November 2018.

Condition 4 – **New dynamic LED system** – set up to provide *constant* lighting – 3-14 December 2018.

What are circadian rhythms?

Circadian rhythms are physical, mental and behavioral changes that follow a daily cycle. Found in most living things, they respond primarily to light and darkness in an organism's environment. Sleeping at night and being awake during the day is an example of a lightrelated circadian rhythm.

Daylight and solar shading guidance

One way of providing circadian lighting is the abundant provision of daylight in buildings. But this can also lead to issues of unwanted solar heat gain and glare unless carefully designed solar shading is provided.

An additional objective of this project, therefore, was to complete production of BRE guidance documents on solar shading. These were a Design manual for solar shading and two BRE Information Papers on retrofitting solar shading and control of solar shading available from:

www.brebookshop.com



The field-study office with LED lighting

Factors that were measured

Site measurements, lighting monitoring and computer modelling were combined with subjective and objective measures of performance – including questionnaires, regular pop-up questions and computer-based performance tests – along with the monitoring of light exposure and level of activity of participants using activity tracking watches.

The responses of the participants to questions and computer-based tests were assessed to identify links between key participant performance indicators – subjective alertness, reaction time and concentration – and the measurement and calculation results of circadian light metrics for each of the four lighting conditions.

Participant answers to general questionnaires following each lighting condition were also analysed and compared to assess the potential impacts of variable lighting. In addition, these results were correlated with the activity level data and the measurements of the site's environmental conditions – temperature and relative humidity.

Research findings

Greater alertness

The average scores for subjective alertness were significantly better with the new dynamic LED system (Condition 2), than with the old constant fluorescent lighting (Condition 1). But comparisons of average subjective alertness scores with the LED systems set up to provide variable lighting (Condition 3), and constant lighting (Condition 4), revealed no statistically significant differences.

Extra light not a factor

Most participants felt more alert under the dynamic LED lighting in Condition 2 compared to the constant fluorescent lighting in Condition 1, but this also happened for the small number of people who received less light in Condition 2. The increase in alertness did not depend significantly on how much extra light people had with the LEDs. All participants received more light in Condition 3 compared to Condition 4, and the increase in light level was much more uniform across participants compared to the first conditions. However, the higher light levels in Condition 3 did not lead to higher scores, on average, for subjective alertness – only half of the participants felt more alert under the dynamic LED lighting (Condition 3).

Other factors not affected

There were no statistically significant differences in test scores for reaction time and concentration and in sleep metrics between the two conditions tested in each phase of the project.

Preference for dynamic lighting

In each phase, participants were asked whether they would prefer dynamic or constant lighting. On average, just over half of them preferred dynamic lighting for their office, typically brighter in the morning and following the variation of natural light outdoors throughout the day. Just under one third preferred the constant lighting.

More questions to answer

Overall, there is still considerable uncertainty about how much light is required for circadian entrainment – i.e. for a person's circadian rhythm to align with the rhythms of light. People vary in their normal daily routines and in how much daylight they are exposed to. In addition, even in a space with 'uniform' electric lighting some people may receive significantly more light into their eyes than others, depending on which way they face.

More research is therefore still needed to understand better the potential impacts of lighting on circadian entrainment and wellbeing in real-life situations, and how to best quantify these in order to produce clear recommendations and guidelines for lighting than can support healthy circadian rhythms and wellbeing.

Outputs

The project findings are described in detail in various outputs, including the following publications:

- Design manual for solar shading (BRE Trust Report) and two BRE Information Papers on retrofitting solar shading and control of solar shading.
- CIBSE Journal article: (www.cibsejournal.com/technical/evalu ating-dynamic-lighting).
- Draft BRE Information Paper on lighting for circadian rhythms.
- Draft papers on findings of the field study for publication in Lighting Research and Technology scientific journal.

Indoor air quality sensors & monitors

Ensuring good indoor air quality (IAQ) requires continuous monitoring, but the quality of the growing numbers of sensors and monitors available is variable and robust protocols for testing them are needed.

This project has investigated the performance of various commercially available VOC and CO₂ sensors/monitors, when challenged by realistic levels of these pollutants generated in controlled environmental chambers at BRE.

Test protocol for standards and assessments

A key aim was to set the foundations for a robust chamber-test protocol for air quality monitors, which can be applied when developing standards against which such monitors may be certified in future. At the same time, it will enable BRE to gauge the performance characteristics that should be applied to monitors specified for use in BREEAM building assessments (e.g. BREEAM in Use).

Actions

The project first identified a range of 'commercial' (i.e. for use on building performance assessment/verification) and 'consumer' (i.e. monitors, watches, etc) devices. The team then developed a test protocol using one of BRE's roomsized environmental chambers, designed for testing devices against Standard Methods of fully-fledged reference analysers when challenged by real-life levels of CO₂ and VOCs. This protocol was then used to test the range of identified devices currently available on the market.

Findings

A number of the devices with CO₂ sensors performed satisfactorily, as perhaps might be expected given

the length of time this type of sensor has been commercially available. However, at normal background CO_2 levels some of the devices overmeasured, and at higher levels (1000-2000 ppm) two types of sensor under-measured by 60-80%.

Several of the devices with TVOC sensors performed unsatisfactorily – with many significantly overmeasuring TVOC when at 'background' chamber conditions, and having very varied responses to higher concentrations. During the project issues with reliability, reproducibility (although only studied here with two replicate devices), connectivity and procurement were also encountered.

Impacts

It is anticipated the findings of this project will heighten awareness of the importance of obtaining good data from air quality monitors – especially where that data may be used to inform financial, reputational or personnel-based decisions.

This limited study has shown that more work is needed to assess the selectivity, accuracy, reproducibility and usability of air quality sensors, which might be used to assess the performance of buildings or to garner credits for environmental assessment schemes. It has helped to underline the very real need for Standard(s) for such air quality monitors.

Next steps

A proposal for developing a BRE Standard for air quality sensors will be submitted to the appropriate BRE teams. The test protocol developed for this project may later be applied to other IEQ parameters such as humidity, CO, NOx and particulate matter. The main findings will also be shared with the BRE Centre for Intelligent Homes team, in connection with their work on Smart buildings.

> IAQ sensor and monitor performance has been investigated in one of BRE's roomsized environmental chambers - the 40m³ chamber pictured here.



Defining KPIs for the built environment

Discussions with industry stakeholders has revealed the need for a definitive list of Key Performance Indicators (KPIs) for measuring and comparing the performance of initiatives to improve sustainability, safety, productivity and quality.

This requires the effective collection of data to feed into benchmarks that are comparable throughout the industry. The currently available benchmarks are often not sufficiently informative or comparable because of inconsistencies in interpretation, piecemeal or unvalidated data capture mechanisms and different reference bases.

This project set out to define and document a broad set of KPIs that can be used to improve sustainability, safety, productivity and quality across the built environment.

Outcomes and findings

The first phase of this work – an Initial Feasibility Study – has been completed and has identified KPIs that are relevant for:

- Built environment sub-sectors and process areas, e.g. construction, house building, infrastructure (energy, water and transport), refurbishment and demolition.
- Broad benchmark themes, e.g. sustainability, safety, productivity and quality.

Using existing KPI publications and feedback from surveys and interviews, a refined list of KPIs has been produced, and comprises KPIs that have been either highlighted as beneficial to industry stakeholders, or may be of interest to them in the future.

This feasibility study has highlighted the large amount of work currently being carried out around KPIs by different groups. It has also revealed that the industry has multiple and conflicting opinions on which issues should be included in KPIs and which should be regulated.

Taking all of the KPIs currently used in the construction sector and condensing them into a definitive list is a considerable task – those currently used vary between each industry subsector and will need to be aligned – but one that should to be undertaken and that offers considerable benefits.

Next steps

To complete the development of a definitive list of Key Performance Indicators for the built environment, the next steps will be to:

- 1. Conduct a detailed analysis of and produce definitions for of each of the KPIs identified in the feasibility study.
- 2. Present these to key stakeholders to validate the definitions and relevance of the selected KPIs.
- 3. Produce and disseminate a KPI Definition Report.



University and studentship reports

New studentship

University news and studentship updates

New Studentship

Using clay in low-carbon cements

The BRE Trust is partnering with Coventry University to offer a fully-funded PhD studentship on *Calcined clays as a reactive alternative to fly ash as a binder in Portland cement concrete*. The successful applicant will study the use of clays as reactive materials for low-carbon cement production.

The project will examine the availability, mineralogy and chemistry of UK clays, their properties and potential use in cement to produce mortars and concretes. It will consider the sustainability, role in carbon footprint reduction and performance in service environments of such materials.

The deadline for applicants is 14 November 2019, with the successful student due to start this three to three-and-a-half year study in January 2020. Further information is available at:

www.coventry.ac.uk/research/researchopportunities/research-students/researchstudentships/calcined-clays-as-a-reactive-alternativeto-fly-ash-as-a-binder-in-portland-cement-concrete





News from Edinburgh University



Professor Grunde Jomaas, BRE Chair of Fire Safety Engineering, reports that, "The group remains very active and is involved in a wide range of activities. Group members attended summer schools, conferences and workshops, for most of which

presentations, posters and papers were given.

"Various group members remain active in committee and standardisation work related to Grenfell Tower, cladding materials, British Standards updates (e.g. BS 8414 and BS 9414), and MHCLG."

Travelling fire tests

Professor Grunde reports that the final phase of the TRAFIR (TRAvelling FIRes) project to characterise travelling fires in large compartments, has now commenced, hosted by University of Ulster at a test site near Enniskillen, Northern Ireland. This work is further to the earlier full-scale travelling fire tests undertaken within the scope of the RFCS-funded TRAFIR project, which included crib fire tests at University of Liège and crib and pool fire experiments at RISE, Sweden.

The first of a series of three full-scale tests in a compartment 15 x 9 x 2.8 m with continuous fuel bed of timber cribs (spruce sticks) took place on 14 June. The University of Edinburgh team supported the test with additional instrumentation (16 thin-skin calorimeters, including an array on the surface of the fuel bed, and additional cameras), lab tests for characterisation of fuel properties and assistance on site in run-up to test. A media article by the University of provides Ulster further details at www.bbc.co.uk/news/uk-northern-ireland-48707462

The main interest for the Edinburgh team is in the associated computational simulations – a priori predictions were logged, and further predictions are now underway for the remaining tests which will explore reduced ventilation conditions but with identical fuel bed. Parallel work is underway on developing generalised fire spread models for these scenarios, most previous work having relied in simple prescriptions of spread rate. The Edinburgh team also attended the 5th coordination meeting for TRAFIR

convened at RISE offices in Gothenburg on 24-25 June. A number of publications related to the project have been generated.



This quarter Dr Angus Law, BRE Lecturer in Fire Safety Engineering, presented his work at Interflam, IFireSS, and Fire and Explosion Hazards. These conference papers are in the process of being shaped into

final journal publications.

Dr Law delivered an evening CPD presentation to the Institution of Structural Engineer's Technical Lecture Series on the subject of Mass Timber and presented at the SEI Structural congress in Orlando.

Combustion Summer School at Princeton University

In June eight students from the BRE Centre for Fire Safety Engineering attended the 2019 Princeton-Institute Combustion Summer School on Combustion. This annual event, organised and hosted by Princeton University, gathers the top researchers and educators in combustion science and engineering to deliver classes on both fundamental and cutting-edge combustion. This year for the first time, a module was included addressing the Combustion Fundamentals of Fire Safety, which relates to much of the research and the overall approach undertaken in the BRE Centre for Fire Safety Engineering.



BRE Centre for Fire Safety Engineering students, with Prof Jose Torero (UCL) and Prof CK Law (Princeton), at Princeton University.



THE UNIVERSITY of EDINBURGH

PhD studentships update

Multi-scale modelling of fires in modern highrise buildings

Ben Ralph

The majority of fire fatalities occur outside of the room of fire origin and are due to smoke inhalation. Two-way fire-building interaction is an important factor in a fire's growth and spread.

This BRE Trust /EPSRC supported project developed a framework for modelling the total building system within industry-accepted timeframes, by using coupled hybrid modelling – the coupling of computationally less expensive models and more expensive models with more fidelity.

The novel model implementation has been benchmarked against medium scale experiments carried out as part of the project and is integrated into the most widely used open source fire model. Ben has concluded the research work on this PhD project, and during this quarter successfully completed his viva.

Testing for knowledge: maximising information obtained from fire tests by using machine learning techniques

Arjan Dexters

Current fire testing procedures to demonstrate the compliance of construction materials with regulations are benchmarked against a specific hazard scenario – so any actual fire exposure will inevitably differ from the test situation (duration, maximum temperature, etc.).

This project aims to develop a machine learning algorithm to predict large-scale test results based on parameters obtained from bench-scale tests. The

method will be particularly useful for assessing and understanding the behaviour of innovative materials and design solutions, and will also allow for a more nuanced ranking than currently offered by the commonly used classification methods for reaction to fire tests.

During this quarter, Arjan prepared and submitted a paper to Interflam, successfully presenting it to a full seminar room and receiving positive feedback.

A fire robustness index for buildings

Vasileios Koutsomarkos

This project aims to develop a fire robustness index for assessing a building's ability to withstand a fire event. It will provide a science-focused and data-reinforced approach that effectively contributes to risk-informed decision making and cost-efficient design solutions. This approach could help designers to go beyond compliance to achieve a higher standard of fire safety than is required by legislation.

During this quarter, the first paper summing up the work up to date was presented at Interflam 2019, and Vasileios had his annual monthly placement at BRE Watford under the supervision of Roger Harrison.



Loughborough University Update

Building energy and environment: measurement, data, analysis and interpretation

Daniel Franks

This project is using occupant and building data to categorise energy use at home. Its principal aims are to understand the changes over time of energy demand and temperatures in English homes, the changes in the socio-economic status of households, and how these interact to produce high energy demand and/or fuel poverty.

New from Bath University



Professor Pete Walker, Director of the BRE Centre for Innovative Construction Materials, reports that the group remains active and involved in a wide range of work, including:

- On-going work on various research projects including:
 - EPSRC project 'RM4L Resilient materials for life'.
 - 2. EPSRC equipment grant 'VSimulators: Building Occupant Interaction Simulator'.
 - 3. EPSRC project 'Assessment, Costing and enhancement of long life, Long Linear assEtS'.
 - 4. EPSRC project 'Autonomous Aerial Robotic Manufacturing'.
- Richard Ball and colleagues are organising the 39th Cement and Concrete Science Conference in Bath (10-11 September 2019).
- 19 journal papers have been published by centre academic staff.
- The Interreg project, 'Sustainable Bio and Waste Resources for Construction', has been completed and new funding has been secured for:
- Circular Biobased Construction Industry. Interreg Project. £400k. August 2019- September 2022. Dan Maskell, Pete Walker, Steve Allen, Steve Emmitt.
- KTP project with Oakwrights. Innovate UK. £300k, Start tbc. Pete Walker and Andy Shea. Three years.
- A new paradigm for engineering microbial induced carbonate precipitation via meso-scale simulations. EPSRC. £90k. Kevin Paine. June 2019-August 2022.



Simulated flooding tests of masonry walls as part of Fiona Gleed's PhD study at the University of Bath.

Bath PhD studentships update

Flood resilience: improving building drying times

Fiona Gleed

Post-flooding reviews have highlighted the need to improve resilience, with drying of buildings identified as a key factor. This study has identified experimental and analytical methods of exploring moisture absorption, migration and desorption during a cycle of flooding and drying, in order to develop a better understanding of the behaviour of masonry wall structures.

Fiona is writing up her thesis having completed this research, and this quarter has had the thesis structure confirmed with some content in all chapters.

Next generation natural fibre reinforced geopolymers

James Bradford

Fibre reinforced polymer composites are widely used in construction, for example in external cladding, modular buildings, bridges, and structural repairs and refurbishments. Conventional fibre reinforced polymer composites use resins and fibres based on fossil fuels.

This project is investigating the use of natural alternatives – geopolymers combined with treated natural fibres – to produce composites with very low embodied carbon. The aim is to deliver the next generation of sustainable, low carbon, fire resistant, creep resistant composite structures.

Work in this quarter focused on the challenge of manufacturing solid samples for the theoretically stronger high-silica geopolymer resins in order to characterise their structural performance.

Inventory Constrained Structural Design

Aurimas Bukauskas

This research project aims to facilitate the greater use of unsawn 'whole timber' that can be obtained from a much wider range of tree types than those used for sawn-timber – the disproportionate demand for which leads to low-diversity, overstocked forests.

During this project an international study exchange facilitated through the Worshipful Company of Engineers' (WCE) Sir Peter Gadsden, Britain-Australia Travel Award, has enabled Aurimas to spend six months studying at the University of Queensland. In this quarter he has made progress on a paper presenting computational methods for inventoryconstrained design, and has engaged with practitioners and researchers in timber construction and fire engineering at the University of Queensland and across Australia.

Self-healing concrete

Lorena Skevi

Self-healing concrete has the potential to transform our building materials, enhance durability serviceability and and reduce maintenance costs. This project aims to develop smart, cement-based materials with self-healing and repairing capabilities, using bacteria that can microbiologically precipitate calcite in cracks. Previous studies show that bacteria-based selfhealing of mortar can return the permeability of cracked mortar to that of uncracked mortar under laboratory conditions. This project is investigating how to ensure that self-healing occurs in concretes in conditions that are present in practice.

During this quarter Lorena continued working on a series of experiments on bacterial concrete in which five different concentrations of bacteria were studied (including one without any bacteria and one with dead bacteria).

Optimising phase change material use for energy-efficient buildings

Ahmad Wadee

Phase-change materials (PCM) can control temperature fluctuations in buildings – and so reduce energy demand – through their ability to store and release thermal energy during phase-change processes (melting and freezing).

At present PCM are not widely applied in construction because of questions over which is optimal for a given use, the means of incorporating them into construction materials, and their longterm performance. This project is exploring more efficient ways of incorporating PCM in the built environment.

This quarter of has seen the continuation of lab work in which lightweight aggregate granules containing phase change materials, manufactured using previously established optimum design conditions, have been incorporated into cement mortar replacing a percentage of standard sand (10%, 20%, 30%, 40%, 50%).

University of Hertfordshire

Civil Engineering courses

The University of Hertfordshire School of Engineering and Computer Science has an important academic partnership with BRE, which is currently delivering BEng and Meng Civil Engineering courses. Building on the success with the first-year courses, they have now delivered to Year 2 students and next year's programme includes Year 3 topics.

First-year students visit BRE for a week to undertake laboratory preparation and testing of concrete, plus tensile testing of steel and assessing the anisotropic nature of timber. They also receive introductory lectures on BIM, BREEAM, CEEQUAL. BRE delivers much of the construction management module to second-year students, and next year's programme will include teaching of the third-year students on sustainable engineering topics as well as supporting final year projects.



Creating concrete test samples – students on the civil engineering course.

Regular dissemination reports

Sales and downloads Events and publications

Sales and Downloads

BRE Bookshop

Retail sales, including those through Amazon and Taylor and Francis International, totalled 778 units for the quarter April to June 2019. This included 326 sales through IHS retail – up from 274 in the previous quarter. IHS sales included two bulk orders of 100 copies of FB 11, *A surveyor's guide to MMC*, and 100 copies of BR 453, *Recognising wood rot and insect damage in buildings*.

Titles which continue to sell well include BR 209, *Site layout planning*, which sold 32 copies (hard copy and pdf), and DG 365, *Soakaway design*, which sold 26 copies in the quarter through all the sales channels.

Subscription sales – the BRE Connect Hard Copy service has been wound up due to lack of material. All customers have been migrated to BRE Connect Online where they have online access to some 1800 BRE publications. At end of June 2019, there were 272 BRE Connect Online subscribers.

Publications due in 2019:

- Thermal insulation: avoiding risks (BR 262) 4E

- Sustainability and fire risk in modern methods of construction (MMC)

- Emergency evacuation of high-rise buildings

- Walls, windows and doors (BR 352) 2E (Harrison, De Vekey, Scivyer et al)

Construction Information Service (CIS)

Analysis of the Top 20 CIS downloads reveal that CIS users value:

- BRE guidance on ground engineering and related subjects with 8 titles in the Top 20 downloads

- the Expert Collections for their convenient format with 5 collections in the Top 20, 2 of which are on sustainability

- reference books on core subjects, eg the building elements: foundations, walls, roofs and floors are all in the Top 20 and floors is at number 21 - guidance on fire-related subjects with 3 titles in the Top 20.

CIS downloads during April-June 2019 totalled 27,637.

Designing Buildings Wiki General performance

By the end of this quarter there were 8321 articles on Designing Buildings Wiki, and the site was visited by 1,993,965 unique users.

Designing Buildings Wiki received 5,182,146 page views, a 37% increase compared to the same quarter in the previous year. The BRE Trust logo appears on every page of the site and so was viewed 5,182,146 times.

BRE articles

By the end of the quarter, there were 398 BRE articles on Designing Buildings Wiki. These can be seen at:

www.designingbuildings.co.uk/wiki/BRE_articles_o n_Designing_Buildings_Wiki

www.designingbuildings.co.uk/wiki/BRE_Buzz_artic les_on_Designing_Buildings_Wiki

This content was viewed 37,037 times during the quarter.

The top 5 BRE articles were:

- BREEAM (3,110 views)
- BRE Digest 365 Soakaway design (1,599 views)
- The daylight factor (1,193 views)
- Electricity supply (1,076 views)
- Site layout planning for daylight and sunlight (946 views).

BREEAM Wiki

There are now 259 articles on BREEAM Wiki. These can be seen at:

https://www.designingbuildings.co.uk/wiki/Categor y:BREEAM.

This content was viewed 24,737 times during the quarter (there may be some overlap between these and page views of BRE articles).

Events and publications

Wellness and biophilia event

An outstanding line up of experts in the use of nature-inspired design to foster workplace wellness, including representatives from major companies such as Marks and Spencer and Akzo Nobel, gave presentations and participated in discussion groups and workshops at the Wellness and Biophilia Symposium on 6-7 June 2019.

Hosted by BRE and supported by the BRE Trust, the symposium addressed such questions as, 'How can nature-inspired design foster workplace wellness?' and 'What are the key interventions that can capitalise on the return on investment in refurbishment? BRE Trust Chief Executive Deborah Pullen gave the opening address to delegates on the Day 2 of the symposium.

The event also marked the launch event for the Biophilic Office, a long-term research and demonstration project from BRE and Oliver Heath Design – to which the BRE Trust is contributing dissemination support – that is gathering evidence for the impacts on people and business of natureinspired design and technology in the built environment.

The event programme can be viewed and presentations downloaded at: www.bregroup.com/conferences/biophilia



Colour workshop at the Wellness and Biophilia Symposium.



BRE Trust Annual Review 2018-19 The BRE Trust Annual Review for 2018-19 is now available as printed copies from the BRE Secretariat (<u>secretariat@bretrust.org.uk</u>) of from the BRE Trust website.

The document provides an illustrated overview of the wide range of research projects, awards, publications and events supported by the Trust, and its extensive activities in partnership with university and other partners.

2018 / 2019 BRE Trust Year Summary



Appendix A: Project Status

People

Research

- The use of innovative solutions and digital technologies to increase safety and wellbeing of people and protect them from the dangers of fire. Trust Contribution £12.5k. Other Contribution £72.5k. Status In Progress
- Life-long health effects of poor indoor air quality. Trust Contribution £15k. Other Contribution £140k. Status Cancelled

Demonstration & Dissemination

• Measuring dementia home adaptation. Trust Contribution - £30k. Other Contribution - £75k. Status - Complete

Property

Research

- Suppression of Biomass Fires. Trust Contribution £5k. Other Contribution £35k. Status Complete
- Centre for Smart Homes. Trust Contribution £53.6k. Other Contribution £81k. Status In Progress
- Circadian lighting effects on health and wellbeing & Solar shading. Trust Contribution £35k. Other Contribution £45k. Status Complete
- 3 Resilience Tackling overheating in urban dwellings. Trust Contribution £40k. Status Stalled
- Optimum replacement of detectors. Trust Contribution £30k. Other Contribution £37.5k. Status In Progress
- Setting standards for IAQ sensors and monitors. Trust Contribution £50k. Other Contribution £25k. Status Complete
- Redevco real estate asset performance. Trust Contribution 80k. Status In Progress
- Redevco QSAND bringing sustainability to post disaster relief. Trust Contribution 100k. Status In Progress
- Definition of KPIs of the Built Environment Feasibility Study. Trust Contribution £15k. Other Contribution £2.5k. Status Complete
- Interpretation of SDGs for application at Infrastructure project level. Trust Contribution £15k. Status Complete

Demonstration & Dissemination

- 100 Years of Council Housing. Trust Contribution £8.9k. Other Contribution £8.25k. Status In Progress
- Adapting with Age. **Trust Contribution** £2.5k. **Status** In Progress
- UK Housing in 2017. Trust Contribution £8k. Other Contribution £11k. Status In Progress

Skills & Learning

• Disseminating knowledge through digital training. Trust Contribution - £40k. Other Contribution - £20k. Status - In progress

Places

Demonstration & Dissemination

• Contribution to the "Guide to creating Positive spaces using pre and Post Occupancy Evaluation". Trust Contribution - £7.7k. Other Contribution - £15k. Status – In Progress

Appendix B: Current Studentships

People (Health, productivity, safety and wellbeing)

Places (community resilience, climate affects)

Social innovation systems for building resilient communities, Donagh Horgan, University of Strathclyde

Development strategies for future cities to ensure energy resilience, Ciaran Higgins (Part-time), University of Strathclyde

Property (efficiently and sustainably, resource efficiency, further proof, house quality)

Low cost approach for characterization of Residential Building stock for energy labelling, *Ioanna Vrachimi, University of Strathclyde*

Whole-Timber Structural Systems, Aurimas Bukauskas, University of Bath

Next generation natural fibre reinforced geopolymers, James Bradford, University of Bath

Optimising phase change material use for energy- efficient buildings, Ahmad Wadee, University of Bath

Developing a Fire Resilience Assessment Methodology for the Built Environment, Vasileios Koutsomarkos, University of Edinburgh

Testing for knowledge: maximizing information obtained from fire test, using machine learning techniques, *Arjan Dexters, University of Edinburgh*

Self-healing concrete, Lorena Skevi, University of Bath

Building energy and environment: measurement, data, analysis and interpretation, Daniel Franks, Loughborough University

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BRE Trust

The BRE Trust uses profits made by BRE Group to fund new research and education programmes, that will help it meet its goal of 'building a better world together'.

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